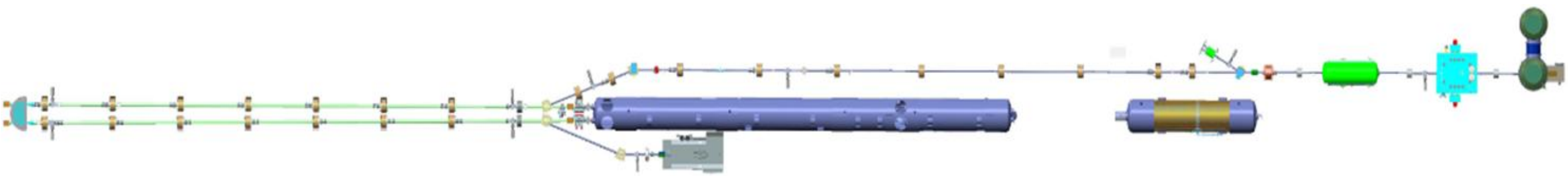
Responses to MAC-2014 Recommendations on Low-Energy RHIC electron Cooling (LEReC)

Alexei Fedotov

for the LEReC team

September 20-21, 2015



General recommendations

- ***Determine from beam simulations what is the highest electron beam current one can operate at without cooling section solenoids being on. Ensure that the beam diagnostics are capable of operating at such current. This might be the current used for the commissioning process.***

  Accurate estimate of this effect should take into account focusing from ion beam. If electron current is too low then there would be significant over focusing from ion beam. Analytic estimates, including effect of ions, show that one should be able to operate with charges up to 30pC (instead of 100-300pC design values) with compensating solenoids OFF. Simulations to confirm this are being planned.

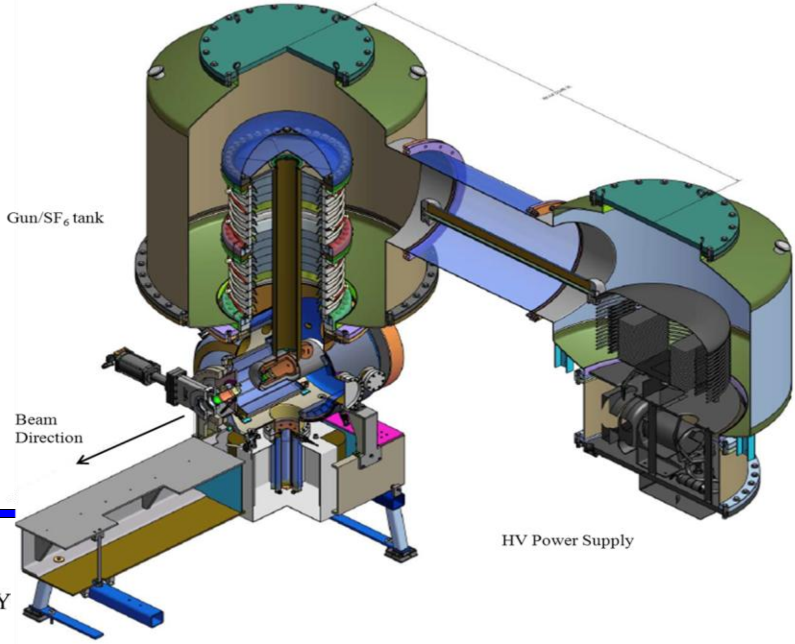
  Instrumentation is presently working with charge of 20-30pC at the ERL. Electronics and necessary amplifiers and filters are being designed to make sure that BPMs in the cooling sections will provide required accuracy at such low charges.

- ***Appoint a single point of contact for the Machine Protection System. Analyze potential catastrophic events (such as loss of vacuum in the electron beam line) and interface to the RHIC MPS to analyze impacts of such events on RHIC.*** TBD

Recommendations for the SRF-gun baseline

- ***Increase the produced bunch charges from the SRF gun toward the design values as soon as is reasonable.***
- ***Measure the beam emittances and energy spread versus bunch charge as soon as is reasonable.***
- ***Establish a set of technical milestones that will allow the choice between the SRF and the DC guns to be made about a year from now.***
- ***Demonstrate 24/7 operation at full specification of the SRF gun.***

In April 2015 decision was made to switch to the DC photoemission gun as a baseline. The SRF gun will be converted to the booster cavity.



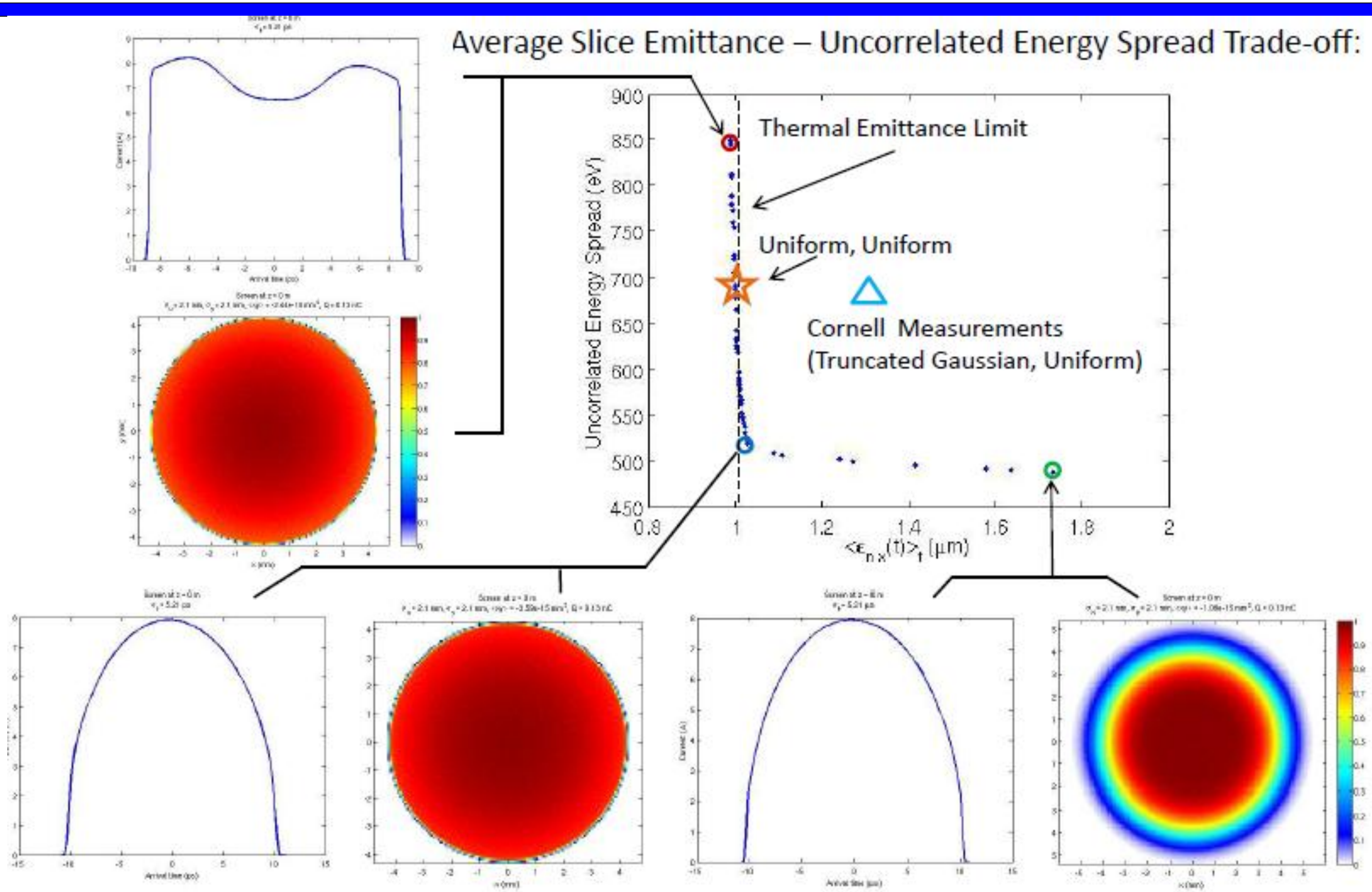
Recommendations for beam dynamics

- ***For further refinement of low energy electron cooling, the choice between SRF and DC guns should be made in the near future.***
- ***Improve the simulation by addressing the deficiencies mentioned above and possibly adopting another simulation code.***

Since April 2015 DC is gun is a baseline. Accelerator Design was optimized for this approach.

The 3-D space charge simulation code General Particle Tracer (GPT) was adopted for realistic simulations. The GPT code is now installed and running at BNL. Also collaboration with Cornell was established. Realistic simulations of LEReC beam transport with the field maps for every element are in progress.

Example of ongoing laser pulse shape optimization with the GPT code (Colwyn Gulliford, Cornell)

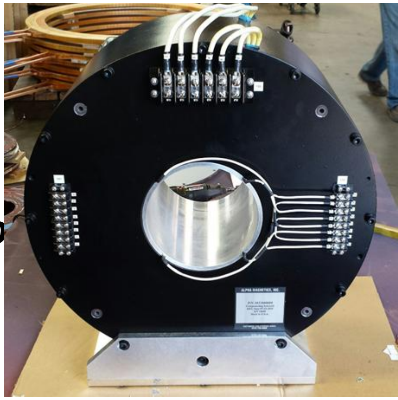


BROOKHAVEN NATIONAL LABORATORY

Office of Science U.S. DEPARTMENT OF ENERGY

System Engineering

- *With respect to the available resources, the installation and commissioning of components for LEReC may be in competition with the set-up of the CeC PoP experiment. In order to avoid delays, an early prioritization should be done by the management for the case of conflicts.* **LEReC is project of the highest priority for the department. This recommendation is being followed as suggested.**



- *The magnetic field axis of the solenoid magnets must be perfectly aligned with respect to the hadron and electron beams. Consider aligning the solenoids with respect to the measured position of the hadron beam (which requires a transfer of the field measurement to the fiducials) and positioning the electron beam with respect to both in a second step.* **Planned.**
- *The Committee has proposed making extensive use of Hall or NMR probes especially to control the integral field strength in the 180° dipole magnet.* **Planned.**
- *Furthermore the Committee suggests following-up tightly the magnet field measurements and fiducialization at the manufacturer's site and to carefully specify the measurement technique and tools for the field measurements.* **Required measurements are specified.**

RF

- ***Pursue the DC gun collaboration agreement with Cornell. Double-check the interface between the SRF and the DC guns to make sure that the SRF gun cavity does in fact need to be reversed to accommodate the DC gun.***

  DC gun for LEReC is presently under construction by Cornell. The SRF gun cavity does not need to be reversed and its present orientation (with power couplers further away from the DC gun) is planned. Design modification to convert gun to the booster cavity are in progress.

- ***Include longitudinal wake fields (the cavity loss factor) into calculations of electron bunch energy spreads as well as the bunch-to-bunch energy spreads.***

  This recommendation was followed in great detail. Accurate estimates of the wake fields and impedance budget showed that electron beam is very sensitive to the wake fields. Some instrumentation devices had to be redesigned to minimize effect of the wake fields. Additional 9 MHz RF cavity was added to compensate bunch-to-bunch spread due to beam loading in the RF cavities. Also feed forward LLRF is being planned.

Example of wake field effects in the cooling sections

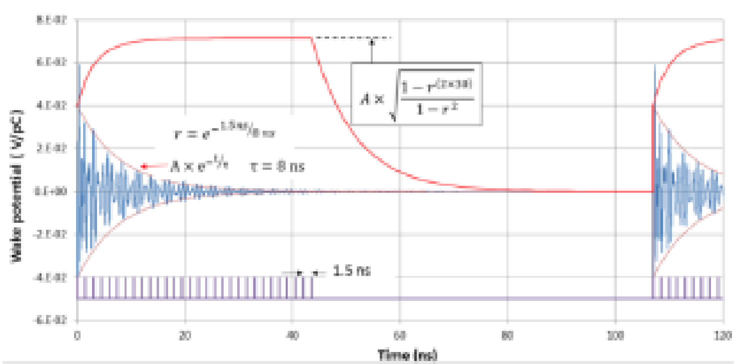
Cooling section energy losses for a 300 pC, 1.5 cm rms long bunch

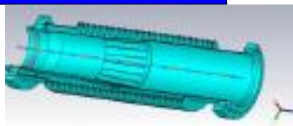
(180 degree magnet chamber and tow welded bellows not yet included)

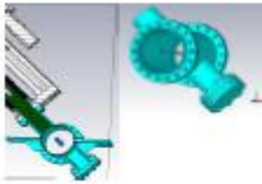
DEVICE	Wake loss factor	Wake loss for 300 pC	Count	Total
	(V/pC)	(eV)		(eV)
Toby's hybrid device	6.28E-02	18.84	2	37.68
Profile monitor	2.33E-02	6.99	2	13.98
Emittance slits	1.68E-02	5.04	2	10.08
BPM	5.30E-03	1.59	14	22.26
Welded bellows	9.07E-02	27.21	2	54.42
Formed Bellows	3.00E-02	9.00	18	162.00
180 degree chamber			1	
40 cm of beam pipe	5.70E-04	0.17	1510"	16.40

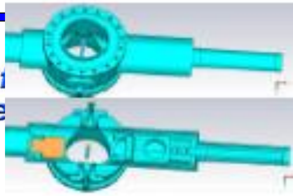
TOTAL 316.82 eV

Estimate of the wake amplitude superposition of the 30 electron bunches using the one-bunch simulation shown on the previous slide. The oscillation amplitude decay is approximated by and exponential. The contributions from individual bunches added in quadrature are elements of a geometric series.





Instrumentation

- ***Evaluate alternative methods for measuring the problematic key performance parameters with high priority.***

  Measurements of most problematic parameters such as energy spread and absolute energy were evaluated in detail and several alternative methods are being pursued.

  A dedicated instrumentation beam line was added which now has RF deflecting cavity for the longitudinal phase space characterization as well as a setup for energy measurement based on an electrostatic spectrometer.

- ***Make sure that the diagnostics in the cooling section (e.g. BPMs) can detect both the ion and the electron beam. One can rely on the ion beam orbit as a reference orbit to adjust the electron orbit***.

  This is being considered in detail. Testing is underway with new BPM hardware to determine whether a single electronics module can be properly calibrated to remove offsets due to the differing frequency responses of the ion and electron beam signals. If not a dual-module approach will be taken where separate channels or boards will be used to individually calibrate the electron and ion signals from the BPM.

Instrumentation (continued)

- ***Start planning for measuring the absolute energies of electron and ion beams. Also, plan on monitoring the electron and ion beam energy stability on-line as a diagnostic tool for cooling.***

  Several complementary measurements of absolute energy of electrons were identified and are being pursued. They include 180 deg. spectrometer magnet with special hybrid BPMs, electrostatic spectrometer with special calibration and time-of-flight measurement at low energies.
- ***Consider simulations to verify the adequacy of the beam-dump shielding.*** TBD
- ***Review the machine protection strategy and its possible failure modes.*** TBD
- ***Evaluate the possibilities (fast scintillators, gated CCD cameras, etc) with a view to developing a capability for resolving the time-structure of bunches within the macro pulses.*** TBD
- ***Initial commissioning strategies of the cooling system and reaching the correct beam parameters should be worked out in detail. As already mentioned, starting with the solenoids switched off may be helpful. In this context, the dynamic range of the instrumentation is important and should be specified clearly. The project should add the dynamic range of the measurement equipment to the table of requirements (min/max).*** The work on this started.